

What Is Claimed Is:

1. A broadband Sagnac Raman amplifier comprising:  
a first reflector;

a second reflector comprising a Sagnac loop mirror  
fabricated from a distributed gain medium and a coupling  
5 means connected to two ends of said Sagnac loop mirror, said  
first reflector and said second reflector forming an optical  
resonator therebetween;

an input port for inputting an optical signal to  
said distributed gain medium;

a pumping means for generating a pumping light to  
10 pump said distributed gain medium; and

an output port for outputting said optical signal  
from said distributed gain medium.

2. The broadband Sagnac Raman amplifier according  
to claim 1, wherein said pumping means is a broadband pump  
15 comprising:

a pump laser having an output port; and

a bandwidth adding mirror connected to said output  
port to generate a broadened pump spectrum.

3. The broadband Sagnac Raman amplifier according  
to claim 2, wherein said bandwidth adding mirror comprises a  
20 Sagnac loop mirror.

4. The broadband Sagnac Raman amplifier according  
to claim 3, wherein said bandwidth adding mirror further  
comprises a coupler with an unequal ratio.  
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5. The broadband Sagnac Raman amplifier according  
to claim 4, wherein said coupler has a ratio of  $f:(1-f)$ , and  
 $0 \leq f \leq 1$ .

6. The broadband Sagnac Raman amplifier according  
30 to claim 3, wherein said bandwidth adding mirror further

comprises a polarization controller located within said Sagnac loop mirror.

7. The broadband Sagnac Raman amplifier according to claim 3, wherein said bandwidth adding mirror further  
5 comprises a phase modulator asymmetrically located within said Sagnac loop mirror.

8. The broadband Sagnac amplifier according to claim 3, wherein said bandwidth adding mirror further comprises an amplitude modulator asymmetrically located  
10 within said Sagnac loop mirror.

9. The broadband Sagnac Raman amplifier according to claim 2, wherein said pump laser is a cladding pumped fiber laser.

10. The broadband Sagnac Raman amplifier according to claim 9, wherein said cladding pumped fiber laser is driven by a modulated pump drive.

11. The broadband Sagnac Raman amplifier according to claim 9, wherein a mechanical modulation is applied to  
20 said cladding pumped fiber.

12. The broadband Sagnac Raman amplifier according to claim 1, wherein said distributed gain medium comprises polarization maintaining fibers cross-spliced at a joint in said Sagnac loop mirror and said coupling means is  
25 polarization maintaining, and said polarization maintaining fibers interchange polarization axes at the cross-splicing joint.

13. The broadband Sagnac Raman amplifier according to claim 12, wherein said coupling means is a coupler having  
30 a ratio of 50:50.

14. The broadband Sagnac Raman amplifier according to claim 12, wherein said coupling means is a bulk 50:50 beam splitter.

15 5 to claim 12, wherein said pumping means is a broadband pump comprising a pump laser and a bandwidth adding mirror attached thereto.

16. The broadband Sagnac Raman amplifier according to claim 12, wherein said input and output ports are  
10 polarization maintaining WDMs.

17. The broadband Sagnac Raman amplifier according to claim 1, wherein said pumping means comprises:

15 a pump laser generating a linearly polarized pumping light; and  
a polarization maintaining fiber,  
said pumping light being launched at a 45 degree angle into said polarization maintaining fiber to produce a beam having two polarization directions.

18. The broadband Sagnac Raman amplifier according to claim 1, wherein said pumping means comprises:

20 a pump laser generating a linearly polarized pumping light;  
a polarization maintaining fiber; and  
a quarter wavelength plate located between said pumping means and said polarization maintaining fiber such  
25 that said polarization maintaining fiber produces a beam having two polarization directions.

19. The broadband Sagnac Raman amplifier according to claim 1, wherein said pumping means comprises:

30 a pump laser generating a linearly polarized pumping light;

a 50:50 coupler dividing said pumping light into a first beam and a second beam;

a retarder located in the path of said first beam to change the polarization direction of said first beam; and

a polarization beam splitter for combining said  
5 first beam and said second beam to produce a beam having two polarization directions.

20. The broadband Sagnac Raman amplifier according to claim 19, wherein said retarder is a half-wave plate.

10 21. The broadband Sagnac Raman amplifier according to claim 19, wherein said retarder is a quarter-wave plate.

22. The broadband Sagnac Raman amplifier according to claim 1, wherein said pumping means comprises:

a pump laser generating a pumping light;

15 a cladding-pumped fiber having two ends, one end being pumped by said pumping light;

a polarization maintaining fiber spliced at a 45 degree angle to the other end of said cladding-pumped fiber to output from said polarization maintaining fiber a beam having two polarization directions.

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23. A broadband Sagnac Raman cascade laser comprising:

a first reflector;

a second reflector comprising a Sagnac loop mirror fabricated from a distributed gain medium and a coupling

25 means connected to two ends of said Sagnac loop mirror, said first reflector and said second reflector forming an optical resonator therebetween;

a pumping means for generating a pumping light to pump said distributed gain medium; and

30 an output port for outputting an optical signal from said distributed gain medium.

24. The broadband Sagnac Raman cascade laser according to claim 23, wherein said pumping means is a broadband pump comprising:  
a pump laser having an output port; and  
a bandwidth adding mirror connected to said output  
5 port to generate a broadened pump spectrum.

25. The broadband Sagnac Raman cascade laser according to claim 24, wherein said bandwidth adding mirror comprises a Sagnac loop mirror.

10 26. The broadband Sagnac Raman cascade laser according to claim 25, wherein said bandwidth adding mirror further comprises a coupler with an unequal ratio.

27. The broadband Sagnac Raman cascade laser according to claim 26, wherein said coupler has a ratio of  
15  $f:(1-f)$ , and  $0 \leq f \leq 1$ .

28. The broadband Sagnac Raman cascade laser according to claim 25, wherein said bandwidth adding mirror further comprises a polarization controller located within  
said Sagnac loop mirror.

29. The broadband Sagnac Raman cascade laser according to claim 25, wherein said bandwidth adding mirror further comprises a phase modulator asymmetrically located  
within said Sagnac loop mirror.

25 30. The broadband Sagnac Raman cascade laser according to claim 25, wherein said bandwidth adding mirror further comprises an amplitude modulator asymmetrically  
located within said Sagnac loop mirror.

31. The broadband Sagnac Raman cascade laser  
30 according to claim 24, wherein said pump laser is a cladding pumped fiber laser.

32. The broadband Sagnac Raman cascade laser according to claim 31, wherein said cladding pumped fiber laser is driven by a modulated pump drive.

33. The broadband Sagnac Raman cascade laser  
5 according to claim 31, wherein a mechanical modulation is applied to said cladding pumped fiber.

34. The broadband Sagnac Raman cascade laser according to claim 23, wherein said distributed gain medium comprises polarization maintaining fibers cross-spliced at a  
10 joint in said Sagnac loop mirror and said coupling means is polarization maintaining, and said polarization maintaining fibers interchange polarization axes at the cross-splicing joint.

35. The broadband Sagnac Raman cascade laser  
15 according to claim 34, wherein said coupling means is a coupler having a ratio of 50:50.

36. The broadband Sagnac Raman cascade laser according to claim 34, wherein said coupling means is a bulk 50:50 beam splitter.  
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37. The broadband Sagnac Raman cascade laser according to claim 34, wherein said pumping means is a broadband pump comprising a pump laser and a bandwidth adding mirror attached thereto.

25 38. The broadband Sagnac Raman cascade laser according to claim 34, wherein said output port is a polarization maintaining WDM.

39. A broadband pump, comprising:  
a pump laser having an output port; and  
30 a bandwidth adding mirror connected to said output port to generate a broadened pump spectrum.

40. The broadband pump according to claim 39,  
wherein said bandwidth adding mirror comprises a Sagnac loop  
mirror.

41. The broadband pump according to claim 40,  
5 wherein said bandwidth adding mirror further comprises a  
coupler with an unequal ratio.

42. The broadband pump according to claim 41,  
wherein said coupler has a ratio of  $f:(1-f)$ , and  $0 \leq f \leq 1$ .

10 43. The broadband pump according to claim 40,  
wherein said bandwidth adding mirror further comprises a  
polarization controller located within said Sagnac loop  
mirror.

44. The broadband pump according to claim 40,  
15 wherein said bandwidth adding mirror further comprises a  
phase modulator asymmetrically located within said Sagnac  
loop mirror.

45. The broadband pump according to claim 40,  
wherein said bandwidth adding mirror further comprises an  
20 amplitude modulator asymmetrically located within said Sagnac  
loop mirror.

46. The broadband pump according to claim 39,  
wherein said pump laser is a cladding pumped fiber laser.

25 47. The broadband pump according to claim 46,  
wherein said cladding pumped fiber laser is driven by a  
modulated pump drive.

48. The broadband pump according to claim 46,  
wherein a mechanical modulation is applied to said cladding  
30 pumped fiber.

49. A broadband Sagnac Raman cascade laser comprising:

a first reflector;

a second reflector comprising a Sagnac loop mirror fabricated from a distributed gain medium and a coupler

5 connected to two ends of said Sagnac loop mirror, said first reflector and said second reflector forming an optical resonator therebetween;

a cladding-pumped fiber located in said optical resonator;

10 a pumping means for generating a pumping light to pump said cladding-pumped fiber; and

an output port for outputting an optical signal from said distributed gain medium.

50. The broadband Sagnac Raman cascade laser according to claim 49, wherein said coupler has a ratio of  
15 50:50.

51. The broadband Sagnac Raman cascade laser according to claim 49, wherein said pumping means is a diode pump array.

20 52. The broadband Sagnac Raman cascade laser according to claim 49, further comprising a polarization controller.

53. The broadband Sagnac Raman cascade laser according to claim 49, wherein said output port is a WDM.  
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54. A broadband Sagnac Raman amplifier comprising:  
a first reflector;  
a second reflector comprising a Sagnac loop mirror fabricated from a distributed gain medium and a coupler  
connected to two ends of said Sagnac loop mirror, said first  
30 reflector and said second reflector forming an optical resonator therebetween;



an input port for inputting an optical signal to  
said distributed gain medium;

a cladding-pumped fiber located in said optical  
resonator;

a pumping means for generating a pumping light to  
5 pump said cladding-pumped fiber; and

an output port for outputting said optical signal  
from said distributed gain medium.

55. The broadband Sagnac Raman amplifier according  
to claim 54, wherein said coupler has a ratio of 50:50.  
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56. The broadband Sagnac Raman amplifier according  
to claim 54, wherein said pumping means is a diode pump  
array.

57. The broadband Sagnac Raman amplifier according  
15 to claim 54, further comprising a polarization controller.

58. The broadband Sagnac Raman amplifier according  
to claim 54, wherein said input port and output port are  
WDMs.

59. The broadband Sagnac Raman amplifier according  
20 to claim 54, further comprising a gain flattening element  
connected to said output port.

60. A broadband Sagnac Raman amplifier comprising:  
a first reflector;  
25 a second reflector comprising a Sagnac loop mirror  
fabricated from a distributed gain medium and a coupler  
connected to two ends of said Sagnac loop mirror, said first  
reflector and said second reflector forming an optical  
resonator therebetween;

an input port for inputting an optical signal to  
30 said distributed gain medium;

a pumping means for generating a pumping light to pump said distributed gain medium, said pumping means being connected to one of said two ends of said Sagnac loop mirror; and

an output port for outputting said optical signal  
5 from said distributed gain medium.

61. The broadband Sagnac Raman amplifier according to claim 60, wherein said coupler has a ratio of 50:50.

62. The broadband Sagnac Raman amplifier according  
10 to claim 60, wherein said pumping means is a pump laser.

63. The broadband Sagnac Raman amplifier according to claim 60, further comprising a polarization controller.

64. The broadband Sagnac Raman amplifier according  
15 to claim 60, wherein said input port and output port are WDMs.

65. A broadband Sagnac Raman cascade laser comprising:

a first reflector;

20 a second reflector comprising a Sagnac loop mirror fabricated from a distributed gain medium and a coupler connected to two ends of said Sagnac loop mirror, said first reflector and said second reflector forming an optical resonator therebetween;

a pumping means for generating a pumping light to  
25 pump said distributed gain medium, said pumping means being connected to one of said two ends of said Sagnac loop mirror; and

an output port for outputting an optical signal from said distributed gain medium.

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66. The broadband Sagnac Raman cascade laser according to claim 65, wherein said coupler has a ratio of 50:50.

67. The broadband Sagnac Raman cascade laser  
5 according to claim 65, wherein said pumping means is a pump laser.

68. The broadband Sagnac Raman cascade laser according to claim 65, further comprising a polarization controller.  
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69. The broadband Sagnac Raman cascade laser according to claim 65, wherein said output port is a WDM.

70. A broadband Sagnac Raman amplifier comprising:  
15 a first reflector;  
a second reflector comprising a Sagnac loop mirror fabricated from a polarization maintaining fiber and a coupler connected to two ends of said Sagnac loop mirror, said first reflector and said second reflector forming an optical resonator therebetween;  
a Raman gain fiber located in said optical  
20 resonator;  
an input port for inputting an optical signal to said distributed gain medium;  
a pumping means for generating a pumping light to pump said Raman gain fiber; and  
an output port for outputting said optical signal  
25 from said distributed gain medium.

71. The broadband Sagnac Raman amplifier according to claim 70, wherein said coupler has a ratio of 50:50.

72. The broadband Sagnac Raman amplifier according  
30 to claim 70, wherein said Sagnac loop mirror comprises a dispersion-shifted polarization maintaining fiber.

73. The broadband Sagnac Raman amplifier according to claim 70, wherein said pumping means is a broadband pump comprising

a pump laser having an output port; and  
a bandwidth adding mirror attached to said output  
5 port.

74. The broadband Sagnac Raman amplifier according to claim 70, wherein said input port and output port are polarization maintaining WDMs.

10 75. The broadband Sagnac Raman amplifier according to claim 70, wherein said first reflector comprises a Sagnac loop mirror fabricated from a polarization maintaining fiber and a coupler connected to two ends of said Sagnac loop mirror.

15 76. The broadband Sagnac Raman amplifier according to claim 75, wherein said coupler of said first reflector has a ratio of 50:50.

20 77. The broadband Sagnac Raman amplifier according to claim 75, wherein said Sagnac loop mirror of said first reflector comprises a dispersion-shifted polarization maintaining fiber.

78. A polarization diversity pumping system, comprising:

a pumping means generating a linearly polarized  
25 pumping light; and  
a polarization maintaining fiber,  
said pumping light being launched at a 45 degree angle into said polarization maintaining fiber to produce a beam having two polarization directions.

30 79. The polarization diversity pumping system according to claim 78, wherein said pumping means is a laser.

80. A polarization diversity pumping system,  
comprising:

a pumping means generating a linearly polarized  
pumping light;

a polarization maintaining fiber; and

5 a quarter wavelength plate located between said  
pumping means and said polarization maintaining fiber such  
that said polarization maintaining fiber produces a beam  
having two polarization directions.

81. The polarization diversity pumping system  
10 according to claim 80, wherein said pump means is a laser.

82. A polarization diversity pumping system,  
comprising:

a pumping means generating a linearly polarized  
pumping light;

15 a 50:50 coupler dividing said pumping light into a  
first and second beams;

a retarder located in the path of said first beam  
to change the polarization direction of said first beam; and

a polarization beam splitter for combining said  
first and second beams to produce a beam having two  
20 polarization directions.

83. The polarization diversity pumping system  
according to claim 82, wherein said pump means is a laser.

84. The polarization diversity pumping system  
25 according to claim 82, wherein said retarder is a half-wave  
plate.

85. The polarization diversity pumping system  
according to claim 82, wherein said retarder is a quarter-  
wave plate.

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86. A polarization diversity pumping system,  
comprising:

a pumping means generating a pumping light;  
a cladding-pumped fiber having two ends, one end  
being pumped by said pumping light;  
5 a polarization maintaining fiber spliced at a 45  
degree angle to the other end of said cladding-pumped fiber  
to output from said polarization maintaining fiber a beam  
having two polarization directions.

87. A two-wavelength broadband Sagnac Raman  
10 amplifier, comprising:

a separating means for separating an optical signal  
to be amplified into a first and second beams, said first  
beam having a different wavelength from said second beam;

a first broadband Sagnac Raman amplifier comprising  
a first reflector;  
15 a second reflector comprising a Sagnac loop  
mirror fabricated from a distributed gain medium and a  
coupling means connected to two ends of said Sagnac loop  
mirror, said first reflector and said second reflector  
forming an optical resonator therebetween;

an input port for inputting said first beam to  
20 said distributed gain medium; and

an output port for outputting said first beam  
from said distributed gain medium;

a second broadband Sagnac Raman amplifier  
comprising

a first reflector;  
25 a second reflector comprising a Sagnac loop  
mirror fabricated from a distributed gain medium and a  
coupling means connected to two ends of said Sagnac loop  
mirror, said first reflector and said second reflector  
forming an optical resonator therebetween;

an input port for inputting said second beam  
30 to said distributed gain medium; and

an output port for outputting said second beam from said distributed gain medium;

a pumping means for generating a pumping light to pump said distributed gain mediums of said first and second broadband Sagnac Raman amplifiers; and

5 a combining means for combining said first and second beams.

88. The two-wavelength broadband Sagnac Raman amplifier according to claim 87, wherein said first broadband Sagnac Raman amplifier is operated at a wavelength of  
10 approximately 1310 nm.

89. The two-wavelength broadband Sagnac Raman amplifier according to claim 87, wherein said second broadband Sagnac Raman amplifiers is operated at a wavelength of approximately 1550 nm.  
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90. A two-wavelength broadband Sagnac Raman amplifier, comprising:

a separating means for separating an optical signal to be amplified into a first and second beams, said first beam having a different wavelength from said second beam;

20 a broadband Sagnac Raman amplifier comprising a first reflector;

a second reflector comprising a Sagnac loop mirror fabricated from a distributed gain medium and a coupling means connected to two ends of said Sagnac loop mirror, said first reflector and said second reflector  
25 forming an optical resonator therebetween;

an input port for inputting said first beam to said distributed gain medium; and

an output port for outputting said first beam from said distributed gain medium;

an erbium-doped fiber amplifier having an input  
30 port and an output port, said input port receiving said second beam;

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a Sagnac Raman cascade laser for pumping said  
erbium-doped fiber amplifier comprising

a first reflector;

a second reflector comprising a Sagnac loop  
mirror fabricated from a distributed gain medium and a  
5 coupling means connected to two ends of said Sagnac loop  
mirror, said first reflector and said second reflector  
forming an optical resonator therebetween; and

an output port for outputting a pumping beam  
from said distributed gain medium, wherein said pumping beam  
pumping said erbium-doped fiber amplifier;

10 a pumping means for generating a pumping light to  
pump said distributed gain media of said broadband Sagnac  
Raman amplifier and said Sagnac Raman cascade laser; and

a combining means for combining said first beam and  
said second beam from said distributed gain medium of said  
broadband Sagnac Raman amplifier and said erbium-doped fiber  
15 amplifier respectively.

91. The two-wavelength broadband Sagnac Raman  
amplifier according to claim 90, wherein said broadband  
Sagnac Raman amplifier is operated at a wavelength of  
approximately 1310 nm.

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92. The two-wavelength broadband Sagnac Raman  
amplifier according to claim 90, wherein said Sagnac Raman  
cascade laser produces a pumping beam having a wavelength of  
approximately 1480 nm.

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93. A two-wavelength broadband Sagnac Raman  
amplifier, comprising:

a separating means for separating an optical signal  
to be amplified into a first beam and a second beam, said  
first beam having a different wavelength from said second  
beam;

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a broadband Sagnac Raman amplifier comprising  
a first reflector;



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a second reflector comprising a Sagnac loop mirror fabricated from a distributed gain medium and a coupling means connected to two ends of said Sagnac loop mirror, said first reflector and said second reflector forming an optical resonator therebetween;

5 an input port for inputting said first beam to said distributed gain medium; and

a pumping means for generating a pumping light to pump said distributed gain medium;

an output port for outputting said first beam from said distributed gain medium;

10 an erbium-doped fiber amplifier having an input port and an output port, said input port receiving said second beam; and

a combining means for combining said first beam and said second beam from said distributed gain medium of said broadband Sagnac Raman amplifier and said erbium-doped fiber  
15 amplifier respectively.

94. The two-wavelength broadband Sagnac Raman amplifier according to claim 93, wherein said broadband Sagnac Raman amplifier is operated at a wavelength of approximately 1310 nm.

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